USDA FOREST SERVICE
RESEARCH PAPER NC-75

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Weights and Centers of Gravity for Red Pine White Spruce Balsam Fir

NORTH CENTRAL FOREST EXPERIMENT STATION
FOREST SERVICE - U.S. DEPARTMENT OF AGRICULTURE

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Manuscript approved for publication February 14, 1972

WEIGHTS AND CENTERS OF GRAVITY FOR RED PINE, WHITE SPRUCE, AND BALSAM FIR

H. M. Steinhilb and John R. Erickson

The information presented here complements that of a previous publication on aspen.[1] These two publications provide equipment manufacturers with a good range of engineering data on which to base the design of machines to harvest and handle northern pulpwood species. Use of these data will help avoid costly over or under-design of the tree harvesting equipment.

Data were obtained from 71 balsam fir and 58 white spruce trees from a site in Houghton County, Michigan, and 58 red pine trees from a site in Baraga County, Michigan. The spruce and balsam fir came from a mixed stand; the red pine came from a pure stand (table 1).

The "tree" reported here is the entire tree above the stump, while the "bole" is the delimbed stem topped to a 3-inch diameter outside the bark. Weight is reported for both the full tree and the bole. The center of gravity location is the distance in feet from the butt to the point of balance of the bole or tree.

Table 1.—Range of variables for balsam fir, red pine and white spruce

Species	D.b.h.	Tree			Bole		
		Height	Green weight	Center of gravity	Length	Green weight	Center of gravity
	Inches	Feet	Pounds	Feet from butt	Feet	Pounds	Feet from butt
Balsam fir	5.0-13.2	30.4-62.0	225-2,255	11.8-23.5	20.8-54.5	135-1,860	8.6-19.3
Red pine	5.6-14.0	50.0-73.8	304-2,562	19.2-29.0	36.2-63.0	255-2,122	15.4-24.6
White spruce	6.2-16.2	31.2-68.0	271-3,292	13.1-28.0	22.5-62.0	135-2,526	8.8-20.3

[1] *Steinhilb, H. M. and John R. Erickson. Weights and centers of gravity for quaking aspen trees and boles. USDA For. Serv. Res. Note NC-91, 4 p., illus. North Cent. For. Exp. Stn., St. Paul, Minn. 1970.*

FIELD PROCEDURES

Sample trees were selected before cutting to include a maximum range of diameters and heights within the stand. Selected trees were bored at breast height to determine moisture content. D.b.h. of each tree was measured and the tree felled directionally to minimize damage. Diameters outside bark at the stump, at 2 and 4 feet from the butt, and a 8-foot intervals thereafter were recorded to a top diameter of 3 inches. The total overall length of the tree and bole above the stump was measured to the nearest 0.1 foot.

Within 2 to 4 hours after felling the tree was lifted with a knuckle boom loader and weighed. The tree was then limbed and topped to a 3-inch diameter outside the bark and the bole lifted and weighed. The lifting device was a free swing sling that contained a weight recording transducer. As the trees and boles were weighed the centers of gravity were located (directly below the apex of the sling).

RESULTS AND DISCUSSION

Regression analysis was used to obtain prediction equations for the weights in pounds and the center-of-gravity locations in feet from the butt of both trees and boles. The resulting prediction equations and standard error of estimate are listed below.

Balsam Fir (71 Samples)

$$\text{Full tree weight} = 10^{0.2935} (\text{d.b.h.})^{2} (\text{tree ht.})^{0.4}$$

$$\text{Value equiv. to S.E. est. is } 10^{\pm 0.0826} = 1.209 \text{ or } \frac{1}{1.209}\ *$$

$$\text{Bole weight} = 10.^{0.1749} (\text{d.b.h.})^{2} (\text{bole length})^{0.4}$$

$$\text{Value equiv. to S.E. est. is } 10^{\pm 0.0857} = 1.218 \text{ or } \frac{1}{1.218}\ **$$

$$\text{Full tree center of gravity} = 4.046 + 0.297(\text{tree ht.})$$

$$\text{S.E. est.} = 0.0208(\text{tree ht.})$$

$$\text{Bole center of gravity} = 4.147 + 0.259(\text{bole length})$$

$$\text{S.E. est.} = 0.0251(\text{bole length})$$

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* *To get points corresponding to one S.E. est. above and below the calculated value, multiply the calculated value by* 1.209 *and* 1/1.209 *respectively.*

***Use same procedure to obtain S.E. est. calculations as was used in full tree wt.*

Red Pine (58 Samples)

$$\text{Full tree weight} = 0.115(\text{d.b.h.})^2\ (\text{tree ht.}) + 1.100(\text{d.b.h.})(\text{tree ht.}) - 4.276(\text{tree ht.})$$

$$\text{S.E. est } 0.0105(\text{d.b.h.})^2\ (\text{tree ht.})$$

$$\text{Bole weight} = -57.3 + 0.1207(\text{d.b.h.})^2\ (\text{bole length}) + 0.699(\text{d.b.h.})(\text{bole length})$$

$$\text{S.E. est} = 0.00838(\text{d.b.h.})^2\ (\text{bole length})$$

$$\text{Full tree center of gravity} = 1.97 + 0.365(\text{tree ht.})$$

$$\text{S.E. est.} = 0.0184(\text{tree ht.})$$

$$\text{Bole center of gravity} = 5.02 + 0.299(\text{bole length})$$

$$\text{S.E. est.} = 0.0127(\text{bole length})$$

White Spruce (58 Samples)

$$\text{Full tree weight} = -81.94 + 10.37(\text{d.b.h.})^2 + 0.0117(\text{d.b.h.})^2\ (\text{tree ht.})$$

$$\text{S.E. est.} = 0.03996(\text{d.b.h.})^2\ (\text{tree ht.})$$

$$\text{Bole weight} = 0.0534(\text{d.b.h.})^2\ (\text{bole length}) + 1.16(\text{d.b.h.})\ (\text{bole length})$$

$$\text{S.E. est.} = 0.343(\text{d.b.h.})(\text{bole length})$$

$$\text{Full tree center of gravity} = 2.93 + 0.3365(\text{tree ht.})$$

$$\text{S.E. est.} = 0.02503(\text{tree ht.})$$

$$\text{Bole center of gravity} = 2.17 + 0.3159(\text{bole length})$$

$$\text{S.E. est.} = 0.0204(\text{bole length})$$

Tree and bole weights are shown in tables 2-4, and centers of gravity of trees and boles are shown in figure 1. A 95 percent upper tolerance limit is given for each d.b.h. and height class to enable harvesting equipment to be designed for near-maximum loads rather than mean loads and thus avoid the underdesign of harvesting machines.

Table 2.—Balsam fir tree and bole weights
(In pounds)

MEAN[1/]

D.b.h. (inches)	Bole length or tree height (feet)								
	20	30		40		50		60	
	Bole	Bole	Tree	Bole	Tree	Bole	Tree	Bole	Tree
5	124	146	192		215		235		
6	178	210	276	236	309	258	338	277	364
7	243	286	375	321	421	350	460	377	495
8	317	373	490	419	550	458	602	492	647
9	402	472	621	530	696	579	761	623	819
10	496	583	766	654	860	715	940	769	1,011
11		706	927	792	1,040	866	1,137	931	1,223
12		840	1,103	942	1,238	1,030	1,353	1,108	1,456
13		985	1,295	1,106	1,453	1,209	1,588	1,300	1,700
UPPER TOLERANCE LIMIT (95 PERCENT LEVEL)[2/]									
5	192	229	296		327		367		
6	274	319	425	370	461	420	513	467	572
7	375	425	580	489	620	554	683	616	760
8	496	550	764	624	807	707	878	786	976
9	639	701	978	779	1,027	877	1,102	975	1,219
10	803	876	1,220	959	1,280	1,070	1,360	1,186	1,493
11		1,077	1,495	1,167	1,565	1,287	1,655	1,420	1,801
12		1,228	1,795	1,405	1,885	1,532	1,987	1,679	2,145
13		1,441	2,235	1,670	2,250	1,806	2,355	1,966	2,527

1/ Mean bole weight was determined from equation:

$$\text{Mean bole weight} = (10)^{.1749}(\text{d.b.h.})^{2}(\text{bole length})^{0.4}$$

Mean tree weight was determined from the equation:

$$\text{Mean tree weight} = (10)^{.2935}(\text{d.b.h.})^{2}(\text{tree ht.})^{0.4}$$

2/ 95 percent or more of the trees or boles in a given class should be below this weight.

Table 3.—Red pine tree and bole weights
(In pounds)

MEAN[1/]

D.b.h. (inches)	Bole length or tree height (feet)									
	30	40		50		60		70		80
	Bole	Bole	Tree	Bole	Tree	Bole	Tree	Bole	Tree	Tree
5	138	203	164		206					
6	199	284	259	370	323		388		452	
7	267	375	363	483	453	591	544	699	635	
8	342	475	476	609	595	741	714	875	833	
9	425	585	598	746	748	907	897	1,068	1,047	
10	515	705	730	896	912	1,087	1,094	1,277	1,277	
11			870	1,058	1,088	1,281	1,305	1,504	1,523	
12					1,275	1,489	1,530	1,747	1,785	
13					1,474	1,712	1,769	2,007	2,064	
14						1,950	2,021	2,284	2,358	
UPPER TOLERANCE LEVEL (95 PERCENT LEVEL)[2/]										
5	157	224	193		242					387
6	223	310	290	402	363		435		508	581
7	298	408	406	525	507	645	609	766	710	811
8	380	518	530	661	663	809	796	957	928	1,061
9	471	642	665	812	832	988	998	1,165	1,164	1,330
10	572	774	812	979	1,015	1,186	1,218	1,394	1,421	1,625
11			870	1,160	1,215	1,402	1,458	1,645	1,701	1,944
12					1,431	1,637	1,718	1,918	2,004	2,290
13					1,665	1,896	1,998	2,214	2,331	2,664
14						2,164	2,299	2,532	2,682	3,066
15									3,057	3,493

1/ Mean bole weight was determined from the equation:

$$\text{Mean bole weight} = -57.3 + 0.1207(\text{d.b.h.})^2(\text{bole length}) + 0.699(\text{d.b.h.})(\text{bole length})$$

Mean tree weight was determined from the equation:

$$\text{Mean tree weight} = 0.115(\text{d.b.h.})^2(\text{tree ht.}) + 1.100(\text{d.b.h.})(\text{tree ht.}) - 4.276(\text{tree ht.})$$

2/ 95 percent or more of trees or boles in a given class should be below this weight.

Table 4.—White spruce tree and bole weights
(In pounds)

D.b.h. (inches)	Bole length or tree height (feet)								
	20	30		40		50		60	70
	Bole	Bole	Tree	Bole	Tree	Bole	Tree	Tree	Tree
MEAN[1]									
5	143	213	186	285	189				
6	177	266	304	355	308	444	312	316	
7	215	322	443	429	449	536	455	461	
8	254	381	604	507	612	634	619	627	634
9	295	443	786	590	796	738	805	815	824
10	339	508	990	677	1,001	846	1,013	1,025	1,037
11	384	576	1,215	768	1,229	960	1,243	1,258	1,272
12		648	1,461	864	1,478	1,080	1,495	1,512	1,529
13				963	1,749	1,204	1,769	1,789	1,809
14						1,334	2,065	2,088	2,111
15								2,409	2,435
16									2,782
UPPER TOLERANCE LIMIT WEIGHT (95 PERCENT LEVEL)[2]									
5	216	324	275	431	333				
6	263	395	409	526	442	658	480	522	
7	312	468	577	624	612	781	661	717	
8	363	545	783	726	817	908	873	946	1,023
9	416	624	1,022	833	1,061	1,040	1,121	1,208	1,304
10	472	708	1,292	944	1,336	1,180	1,402	1,504	1,621
11	531	796	1,592	1,062	1,644	1,327	1,718	1,834	1,972
12		889	1,922	1,186	1,982	1,482	2,067	2,196	2,357
13				1,317	2,349	1,647	2,446	2,592	2,777
14						1,820	2,857	3,021	3,233
15								3,483	3,722
16									4,245

1/ Mean bole weight was determined from the equation:

$$\text{Mean bole weight} = 0.0534(\text{d.b.h.})^2(\text{bole length}) + 1.16(\text{d.b.h.})(\text{bole length}).$$

Mean tree weight was determined from the equation:

$$\text{Mean tree weight} = -81.94 + 10.37(\text{d.b.h.})^2 + 0.0117(\text{d.b.h.})^2(\text{tree ht.})$$

2/ 95 percent or more of trees or boles in a given class should be below this weight.

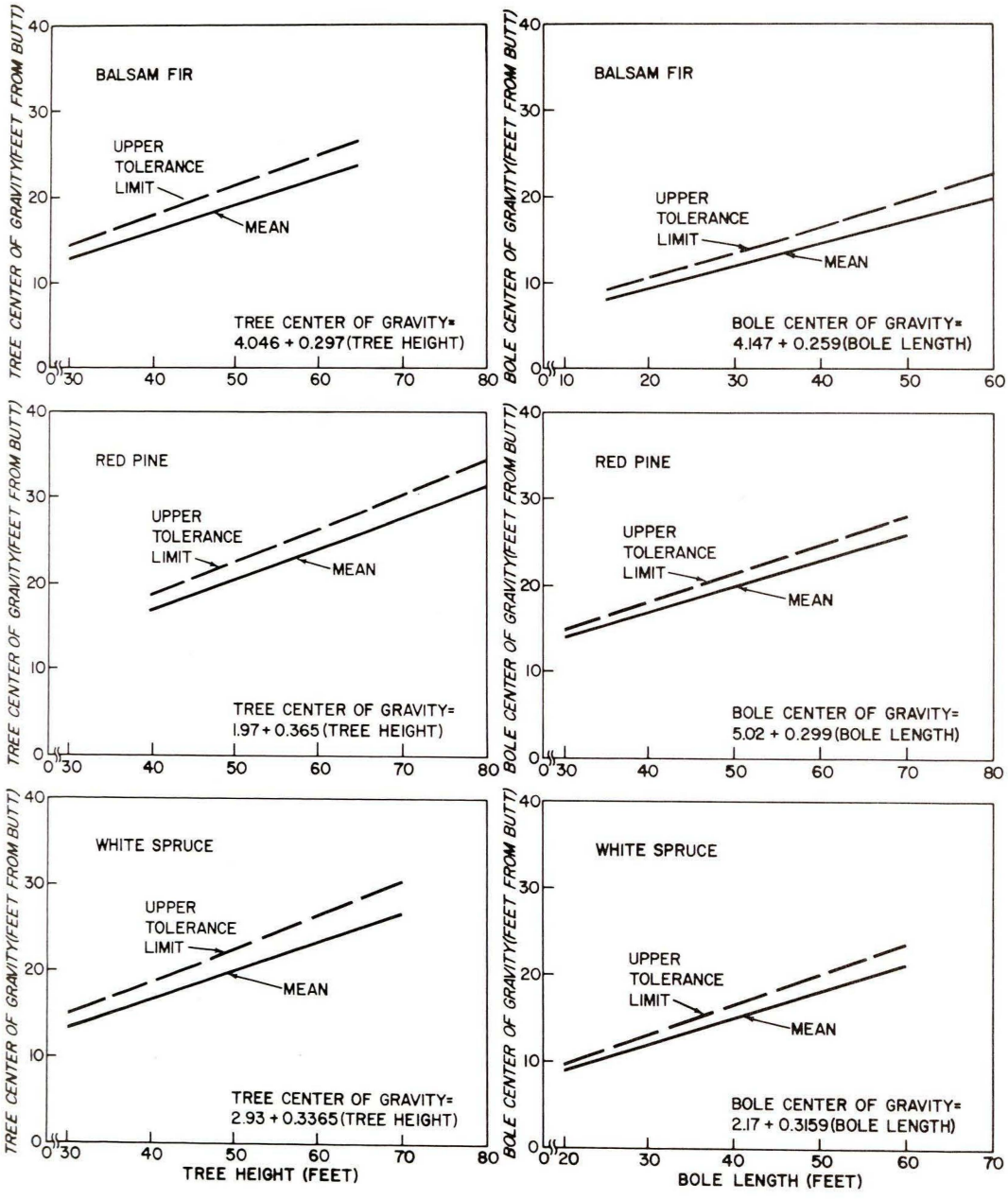
BALSAM FIR
UPPER TOLERANCE LIMIT
MEAN
TREE CENTER OF GRAVITY= 4.046 + 0.297(TREE HEIGHT)
TREE CENTER OF GRAVITY(FEET FROM BUTT)
BOLE CENTER OF GRAVITY= 4.147 + 0.259(BOLE LENGTH)
BOLE CENTER OF GRAVITY(FEET FROM BUTT)
RED PINE
TREE CENTER OF GRAVITY= 1.97 + 0.365(TREE HEIGHT)
BOLE CENTER OF GRAVITY= 5.02 + 0.299(BOLE LENGTH)
WHITE SPRUCE
TREE CENTER OF GRAVITY= 2.93 + 0.3365(TREE HEIGHT)
BOLE CENTER OF GRAVITY= 2.17 + 0.3159(BOLE LENGTH)
TREE HEIGHT (FEET)
BOLE LENGTH (FEET)

Figure 1.—Centers of gravity for balsam fir, red pine, and white spruce trees and boles.

☆U.S. Government Printing Office

SOME RECENT RESEARCH PAPERS OF THE NORTH CENTRAL FOREST EXPERIMENT STATION

Site Index Curves for Black, White, Scarlet, and Chestnut Oaks in the Central States, by Willard H. Carmean. USDA For. Serv. Res. Pap. NC-62, 8 p., illus. 1971.

Wilderness Ecology: Virgin Plant Communities of the Boundary Waters Canoe Area, by Lewis F. Ohmann and Robert R. Ream. USDA For. Serv. Res. Pap. NC-63, 55 p., illus. 1971.

Management Guide for the Black Spruce Type in the Lake States, by William F. Johnston. USDA For. Serv. Res. Pap. NC-64, 12 p., illus. 1971.

Site-Index Comparisons for Tree Species in Northern Minnesota, by Willard H. Carmean and Alexander Vasilevsky. USDA For. Serv. Res. Pap. NC-65, 8 p., illus. 1971.

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Annotated Bibliography of Walnut—Supplement No. 1, by Martha K. Dillow and Norman L. Hawker. USDA For. Serv. Res. Pap. NC-70, 23 p., 1971.

Fire Whirlwind Formation Over Flat Terrain, by Donald A. Haines and Gerald H. Updike. USDA For. Serv. Res. Pap. NC-71, 12 p., illus. 1971.

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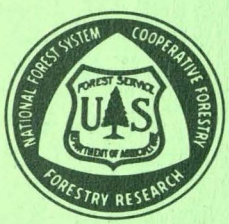

- Conducting forest and range research at over 75 locations ranging from Puerto Rico to Alaska to Hawaii.
- Participating with all State forestry agencies in cooperative programs to protect, improve, and wisely use our Country's 395 million acres of State, local, and private forest lands.
- Managing and protecting the 187-million acre National Forest System.

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